Large-Scale Aerosol Modeling and Analysis

Douglas L. Westphal
Naval Research Laboratory, 7 Grace Hopper Ave, Stop 2, Monterey, CA 93943-5502
phone: (831) 656-4743   fax: (408) 656-4769   email: westphal@nrlmry.navy.mil

Cynthia A. Curtis
Naval Research Laboratory, 7 Grace Hopper Ave, Stop 2 Monterey, CA 93943-5502
phone: (831) 656-4022   fax: (831) 656-4769   email: curtis@nrlmry.navy.mil

Annette L. Walker
Naval Research Laboratory, 7 Grace Hopper Ave, Stop 2 Monterey, CA 93943-5502
phone: (831) 656-4722   fax: (831) 656-4769   email: walker@nrlmry.navy.mil

LONG-TERM GOALS

The long-term goal of this research is to develop a practical predictive capability for visibility and weather effects of aerosol particles for the entire globe for timely use in planning and executing DoD operations and activities. The fundamental predicted variables are the concentrations of atmospheric aerosol particles responsible for degradation of EO propagation in regions of DoD interest. Post-processors calculate the optical parameters useful in strategic and tactical planning, training, and operational activities. This forecast and simulation capability also is used in theoretical studies of the Earth's atmosphere and has operational usefulness in scientific field campaigns.

OBJECTIVES

The objective of this project is to investigate, develop, and test aerosol initialization, source, and prediction schemes. These will be incorporated into an aerosol data assimilation and prediction system based on observations, aerosol process models, and meteorological models.

APPROACH

The approach to the problem of aerosol and Electro-Optical (EO) extinction prediction follows the method used in numerical weather prediction, namely real-time assessment for initialization of first-principles models. The Naval Research Laboratory has developed a new capability for forecasting the global and regional concentration of atmospheric particulate matter and the subsequent effects on visibility. The regional model (COAMPS/Aerosol) became operational during OIF. The global model Navy Aerosol Analysis and Prediction System (NAAPS) became operational in October 2005. These models allow the prediction of the concentration of the dominant visibility reducing aerosol species up to six days in advance anywhere on the globe. NAAPS and COAMPS are particularly useful for forecasts of dust storms in areas downwind of the large deserts of the world: Arabian Gulf, Sea of Japan, China Sea, Mediterranean Sea, and the Tropical Atlantic Ocean. NAAPS also accurately predicts the fate of large-scale smoke and pollution plumes.   With its global and continuous coverage,

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14. ABSTRACT
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15. SUBJECT TERMS

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NAAPS is invaluable in filling the gaps in observations of aerosol particles and visibility and in satellite observations and extends our understanding of aerosol particles and their impact on Navy operations. However, validation studies indicate that the forecasts would benefit from increasing the resolution and the number of species and the implementation of aerosol data assimilation.

WORK COMPLETED

We identified origin of dust plumes impacting naval operations in the Red Sea, Mediterranean, eastern Atlantic, Gulf of Guinea, Sea of Japan, Yellow Sea, and East China Sea by applying the technique used to develop the NRL high-resolution (1 km) dust source database for the Middle East and SW Asia (Walker et al., 2007). We recorded the erodible land surface information in the newly created 1-km dust source databases for North Africa and Northeast Asia. We transitioned v0.1 of NRL NE Asia dust source database to 6.4. We continued development and improvement of the NRL high-resolution dust source database for the Middle East and Southwest Asia.

The collaboration with Scripps Institute of Oceanography and the University of Warsaw has led to the addition of a sea salt component to NAAPS. The physics include emission from the water's surface, vertical and horizontal advection and diffusion, dry and wet deposition, and gravitational sedimentation. This version of the code has been validated for several field campaigns (Witek et al., 2007), and is running on NRL machines and used for research. More extensive validation is underway. Transition to operations is expected in FY08.

NAAPS was improved by the addition of an aerosol data assimilation capability. The data assimilation package is a version of the NRL Atmospheric Variational Data Assimilation System (NAVDAS) modified to assimilate MODIS aerosol optical depths (Zhang et al., 2007). The package was received (from J. Reid, NRL) and has been converted for use in a daily research mode. More extensive validation is underway. Transition to operations is expected in FY08.

NAAPS forecasts of CONUS dust storms and long-range dust transport to CONUS were further evaluated in collaboration with CSU. These results have been reported in Wells et al. (2007). NRL researchers continue to interact and collaborate with outside researchers through the use of NAAPS data for explaining various aerosol transport phenomena around the world, both in real time and in the research mode. These collaborations result in a better understanding of the atmosphere, an improved NAAPS model, peer-reviewed publications and conference proceedings.

RESULTS

North American dust production was investigated further. Observed anomalously-high summertime dust emissions in NAAPS were hypothesized to be related to one of the following:

1. Underestimation of soil mass concentrations from the IMPROVE samples

2. A high bias in NOGAPS surface wind speeds near source regions, generating dust too readily and in too-high concentrations

3. Excessively strong dust source functions or inappropriate emissions thresholds

With regard to Hypothesis 1, our analyses showed that our estimates of coarse mode dust concentrations are likely to overestimate dust contributions. For Hypothesis 2, a comparison of NOGAPS wind fields to NCEP reanalysis surface winds over dry and desert regions of the U.S. suggests that NOGAPS has a slight low bias, making option (2) an unlikely explanation for anomalously-high simulated dust concentrations. To study (3), a sensitivity simulation with an increased threshold friction velocity eliminated some of the highest values but created a low bias in predicted concentrations and reduced the overall skill of the model. Further investigation is required to understand this problem.

NAAPS was used to study the transatlantic transport of dust-borne microorganisms from the arid lands of northwest Africa to the Caribbean and Americas. The study presents evidence of early summer survival and transport of microorganisms from North Africa to a mid-Atlantic research site. Additionally, the statistical correlation between the NAAPS model dust concentrations and microbial CFU counts observed demonstrates the potential for using models to address the global dispersion of microorganisms (nonpathogenic and pathogenic) and other soil associated constituents as they pertain to ecological evolution and ecosystem and human health.

The physical and chemical characteristics of springtime atmospheric aerosol particles in Colorado, including those which act as heterogeneous ice nuclei (IN), were investigated. Based on the NAAPS analysis, it appears that dust layers from long-range transport having a measurable impact on surface aerosol soil concentrations typically arrive first in the upper atmosphere, then at lower altitudes, and finally at the surface after several days. Based on modeled dust vertical profiles, dust concentrations aloft can be significantly higher than those observed at an elevated surface site, which implies that stronger impacts of dust on IN concentrations might be expected in clouds higher altitudes.

A case of long range transport of Saharan dust over a pathway spanning Asia and the Pacific to Western North America has been documented for the first time. A combination of NAAPS output, lidar, sunphotometer and high altitude surface monitoring observations confirmed the presence of a dust layer over western North America on 13-14 March 2005. Dust layers in the free troposphere were observed with lidars in Suwon, Gosan, Tsukuba and Vancouver. On the basis of sunphotometer data and surface observations in British Columbia it appears that this event had only a weak impact on near surface particulate concentrations and aerosol optical depths. However, the significance of the observations rests in identifying a case of very long range transport of dust (~19,000 km) over an intercontinental pathway not previously documented.

IMPACT/APPLICATIONS

NAAPS helps to satisfy the Navy's long-term goal of a predictive capability for aerosol particles and EO propagation. The forecasts of aerosol concentration are distributed via NIPRNET and SIPRNET for use by DoD forecasters, operators, planners, and aviators (http://www.nrlmry.navy.mil/aerosol/). The model output is processed by FNMOC and converted into the fundamental optical properties required to calculate EO propagation. These properties are used to populate the Tactical Environmental Data Server (TEDS) and subsequently used by the Target Acquisition Weapons Software (TAWS) to calculate slant-path visibility. The forecasts are used to correct satellite retrievals of sea surface temperature (SST) by NAVO, thus improving tropical forecasts.

NAAPS also provides tools for the 6.1 and 6.2 aerosol research communities and the academic community. NAAPS data continues to be used in interactions with research community appearing in

peer-reviewed and conference papers. Over the year, collaborations have occurred between NRL and the University of Warsaw, Scripps Institute of Oceanography, Colorado State University, USGS, Université de Sherbrooke (Quebec), U. British Columbia, Environment Canada, University of Washington, Harvard University, and others. NAAPS forecasts enhance NRL's continued participation in field programs and will give us further opportunities for collaboration and access to important validation data.

TRANSITIONS

NAAPS has been operational at FNMOC since September 2005. Improvements to NAAPS (as developed in this work unit) are transitioned to FNMOC via 6.4 funding provided by PMW-120.

RELATED PROJECTS

The NRL 6.1 "Atmospheric Physics" and the NRL 6.2 "Advanced Moist Physics Modeling" programs use NAAPS data and products for initialization, investigations and validation. ONR 6.2 "Aerosol Microphysics and Radiation" supports improvements in NAAPS physics and model initialization. The improvements to NAAPS and the implementation of NAAPS and FAROP at FNMOC are supported by PMW 120 6.4 "Large-scale Atmospheric Models" and 6.4 "Small-scale Atmospheric Models." This funding also supports development and generation of products for use by the fleet.

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HONORS/AWARDS/PRIZES

None.
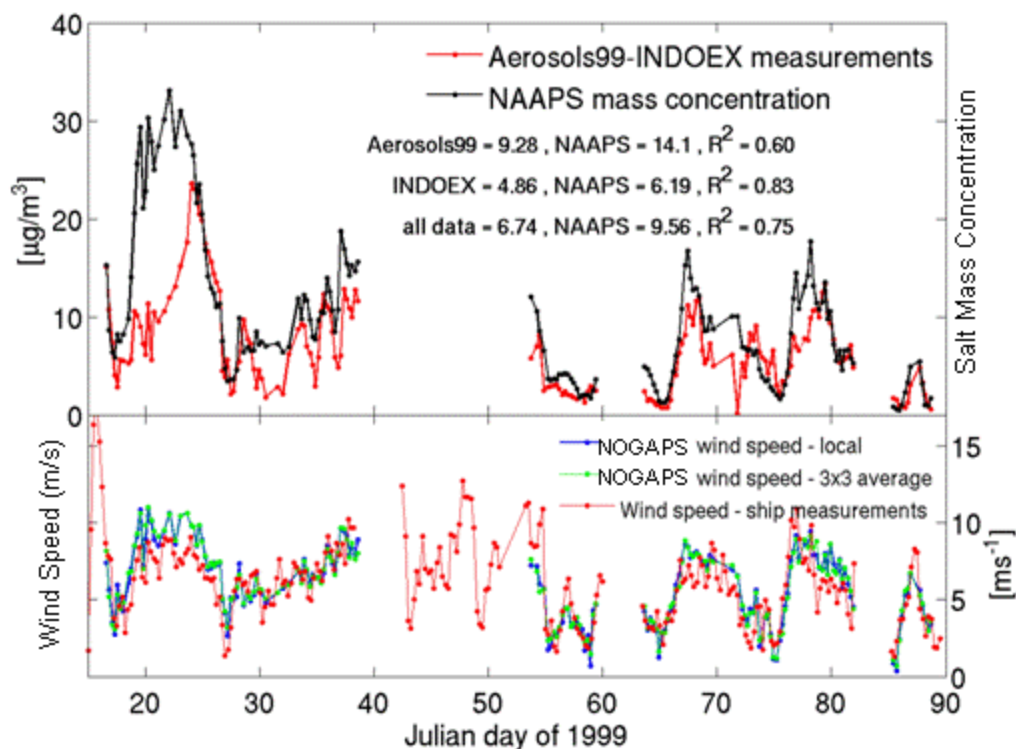
Figure 1. Top panel, comparison of the model concentrations with measurements during Aerosols 99-INDOEX experiment; bottom panel, measured and NAAPS-modeled wind velocity during the cruise. Witek et al. (2007) [graph: Two panels. top panel shows NAAPS simulations capture most of the roughly 10- to 20-day periodicity in measured sea salt, with the exception of over-predicting the concentration by a factor of two early in the period. Bottom panel shows NOGAPS wind speeds in very good agreement]
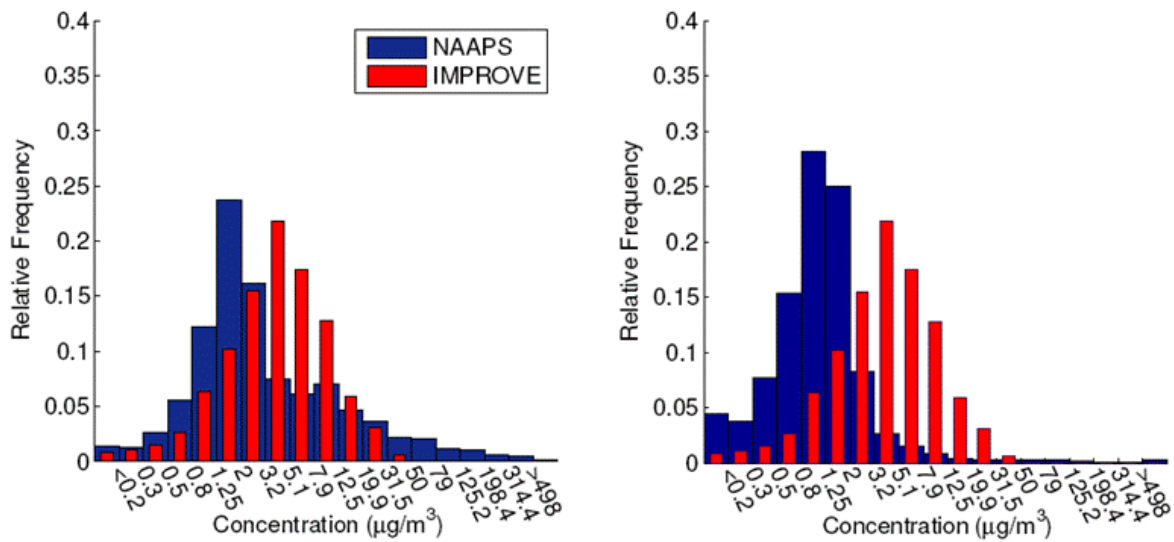
Figure 2. Aug-Oct 2004 IMPROVE and NAAPS simulated surface concentration frequency distributions (µg m-3) for threshold friction velocity set to 60 cm s-1 (left) and 80 cm s-1 (right) for all western sites. [graph. Left panel shows NAAPS predicts a distribution similar to that observed, but the NAAPS mode is lower and there are some very high concentrations. Right panel shows the high concentrations have been reduced, but the mode has also been further reduced.]